HTSM Lighting roadmap

[total size per roadmap is 7 pages, including artwork and tables]

1. Societal challenges and economic relevance

Introduction

Lighting accounts for 19% of the global electrical energy use. Between 2010 and 2050 the demand for lighting is expected to triple. With the advent of the 24/7 economy, human activity is no longer limited to the daytime. By mimicking daylight, more natural illumination conditions can be created, which will positively impact people's health and well-being. Only by embarking in intelligent lighting systems based on SSL (Solid State Lighting) and using natural daylight as an integral part of these intelligent lighting systems, we will be able to cope with the tripling in demand for artificial light, while stabilizing its energy use at its present level. Next to its impact on energy efficiency the transition to SSL has enabled much more efficient use of scarce materials. Further research must enable innovative technologies, modular designs and business models to implement cradle-to-cradle product chains.

Lighting is increasingly becoming connected, both the Lighting systems itself and in connection with other systems in the built environment. Its ubiquitous presence offers the perfect infrastructure for web access anytime, anywhere for all citizens. By exchanging data with other systems at the building and city level one will be able to offer far superior overall solutions improving people's life. Currently, lighting is becoming an integral part of the Internet of Things, enabling inclusive, innovative and reflective societies which will further unlock the added value of *lighting beyond illumination*.

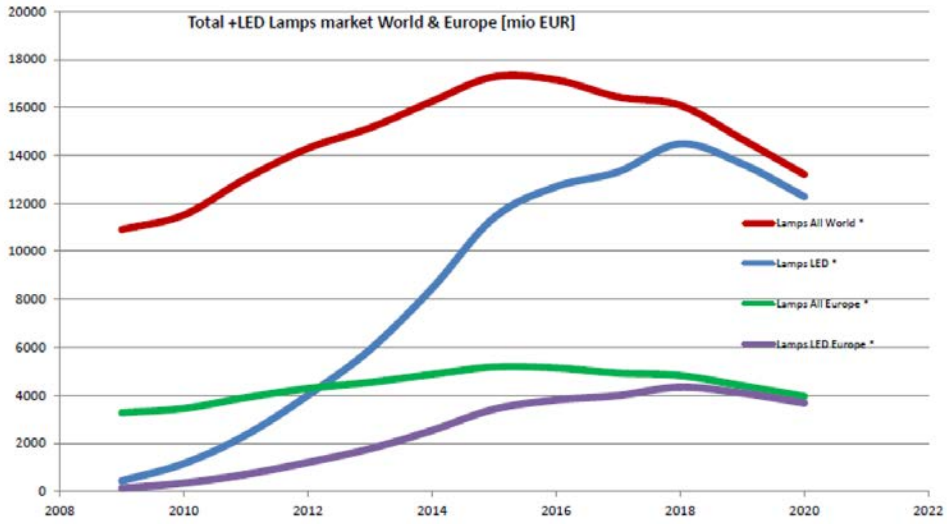
Societal challenges addressed in this roadmap

For each of the following societal themes, the innovations in lighting will contribute:

- Health: With light for health & wellbeing lives can be improved: e.g. seasonal affected disorder-free buildings can be created, patients recover faster with the right light and health related cost can be reduced.
- Safety: In the outdoor space, lighting plays a crucial role to improve road safety and the perception of safety in the street. Using new light effects these safety aspects can be further enhanced as well as lighting can be used for active crowd management. New optical solutions will reduce light pollution and improve wildlife.
- Climate: Current developments in SSL technology still allow the energy usage of current state-of-the-art to be halved. In a second phase, SMARTification will further drive the energy consumption down by selectively switching off the lighting without compromising the performance. Furthermore, horticulture will benefit from dedicated and optimized LED lighting that allows amongst other city-farming.
- Sustainability: To make circular economy for lighting come through new technical interfaces that allow easy maintenance and upgradeability as well as new business models that support circular models need to be developed.

World-wide market for this roadmap, now and in 2025

The world-wide market for lighting products, covering both light sources and luminaires, is estimated to grow from € 50 billion in 2010 to €100 billion by 2020. While LEDs accounted for more than 40% of the turnover of the leading lighting companies early 2015, by 2020 nearly all lighting sales will go to LED based solutions. The growth of the connected lighting market is expected to be very important; its revenue growth will reach $56.05 billion by 2020, at an estimated CAGR of 15.8% from 2014 to 2020. Consequently, the lighting industry is faced with an unprecedented transformation in its 130 years of existence.



Light source market value (in M€)

Competitive position of the NL ecosystem (market and know-how)

The Netherlands has a unique position of strength in the lighting market. The largest global player in lighting is rooted in the Netherlands, its 2017 turnover equalling 160% of the second and 310% of third global player. Philips Lighting is the world leader in lamps with a market share of around 20% and the only global player in both professional and consumer luminaires. Next to this around 350 SMEs active in the lighting domain are registered with the Dutch Chamber of Commerce, while a substantial knowledge base in solid state technology, optics, embedded software and lighting is found with academia and research institutes, opening access to all competences needed for the future.

By becoming the motor of intelligent lighting, the Dutch lighting eco-system will be able to consolidate its number one position in lighting, both in terms of economic growth and of employment, despite the advent of Asian players that are currently driving the cost roadmap of LEDs and LED retrofit lamps.

Because the Dutch government owns a substantial part of the lighting infrastructure, i.e.: outdoor lighting and public buildings, it is in a perfect position to take the lead in the validation of the R&D results under real life conditions.

2. Applications and technologies

State of the art review (industry and science)

Currently, LEDs are primarily used as replacements of conventional light sources, with a penetration of 15% in the total market. The lighting market will continue to grow with a CAGR of 3% and the LEDification will continue at a rapid pace and reach a level of more than 50% in 2025.

Developments in present and future markets and societal themes

On energy usage, present LED technology has an efficacy around 160 lm/W. The coming years the efficacy will rise above 250 lm/W for current LED technologies and even potentially above 320 lm/W for new LED architectures. To reach these levels, deep understanding of the physical mechanisms behind LED lighting as well as a deep understanding of the perception aspects of multi-coloured LED architectures need to be understood in more detail.

Today, one of the limiting factors in the usage of LED technology embedded in building elements is the size of the driver. Further driver miniaturization is needed. Solutions are to be found in the usage of GaN type of electronic components that allow higher switching frequencies. Commercially, these components start to be available, but the optimized designs still must be found.

Advances in conversion materials are needed to a) allow higher efficacies and b) allow tailored spectra. To reach the high efficacies mentioned above, there is a need for red and green conversion materials with a narrow bandwidth. In addition, there is a strong trend in industry to go to tailored spectra such that the light can be adjusted to the application. Human centric lighting is enabled by these new spectra and allows the industry to make light that supports bio-rhythms, improves concentration and light that is visually more pleasing.

Both in the consumer and in the professional space connected lighting systems are on the rise and the added value of such Internet-of-Things systems is ever more appreciated. The added value of lighting beyond illumination and energy efficiency has a business potential outnumbering the present component and system business by at least a factor of two.

To create these connected lighting systems that harvest data, the lighting industry needs access to sensor technology that is cheap, reliable and tailored to the task at hand. In the current industry we see the inroad of micro-wave and thermopile type of sensors. These sensors need dedicated signal processing to extract the data in real-life applications. At this moment in time, these algorithms are not available yet.

Questions and milestones for this roadmap in 2025

It is proposed that advancement of the state-of-the art in lighting technology will be approached from three different angles, representing the sub-eco-systems of lighting in the Netherlands:

A. Breakthroughs in LED technology: excellence in science
    a. New SSL source architectures (micro- and nano-LED, laser sources)
    b. New design methodologies for optical components and new optical solutions
    c. New conversion technologies, materials and basic understanding of the scattering behaviour of these materials
    d. Spectral engineered solutions to address new markets like Human Centric Lighting, horticulture etc.
    e. Reliability models and degradation mechanisms of the sources and full systems

B. Innovation at the SSL system level: This is a bottom-up approach in leveraging the new opportunities that the recent advent of SSL devices has provided for lighting systems (opportunity driven technology push). Challenges that we foresee here are:
    a. Smaller LED solutions, miniaturized driving solutions for unobtrusive solutions, based on e.g. IC integration and GaN components.
    b. Integrated optical, thermal solutions allowing function integration and long-lifetime solutions
    c. Hard- and software reliability to allow upgradable, reliable solutions and to safeguard all user requirements on complex lighting systems.
    d. New applications and segment specific solutions based on spectral tuning (horticulture, light for farming, human centric lighting applications etc).
C. Creating added value beyond energy efficiency: this is a top-down approach in establishing lighting solutions that addressing the user needs (requirements driven market pull). Intelligent lighting systems are the foundation for services improving quality and reliability of illumination. Next to this data exchange between the lighting systems and other verticals in the built environment will enable the realization of unsurpassed overall solutions serving people's needs.
    a. User insight generation, claim validation and user acceptance as enabler for energy reduction, cost reduction, productivity, safety, crowd control, health and well-being realized through high tech systems and materials
    b. User-system interaction technologies and concepts, user interface development, end-user programming
    c. System of system integration: lighting system integration with other embedded intelligence systems, such as building management and domotics, video surveillance, smart grids or traffic management systems.
    d. Life science and health roadmaps providing deep understanding on the impact of lighting on human cognition.
    e. (Near) real life data analytics supporting lighting services and services beyond lighting, bridging the lighting roadmap with the ICT roadmap.

3. Priorities and implementation

Implementation of this roadmap in public-private partnerships and ecosystems

In the recent years, fruitful collaborations in the Dutch lighting innovation eco-system were initiated, resulting in many collaborations established in public-private partnership projects like (not exhaustive): OpenAIS (Photonics PPP – H2020) CSSL, EnLight, GreenElec, OPERA (all ENIAC), Hertz, SEEL (all CATRENE), ISLES 2014 (Point-One), Aeviom, Fast2Light, Place-IT, Flex-o-Fab, MMP, Terasel, SSL-erate, Clean4Yield, IMOLA (all FP7), DIMAP, PhotoLED (H2020), Demanes, DEWI (ARTEMIS), IoSense, SCOTT, DELPHI4LED (ECSEL), PS-CRIMSON (ITEA3) and a FOM_IPP on "Improved Solid State Light Sources". Additionally, the H2020 / KIC / EIT Digital projects BrightAgeing, "Elevators & Lighting", ALIGRE and LumiPark explored the requirements for market introduction of connected lighting applications.

The EUREKA programmes ITEA3 and PENTA, as well as the ECSEL JU – most relevant to HTSM – have experienced prominent Dutch participation in the recent past. Hence, the Dutch lighting eco-system wants to continue this extensive collaboration, also with the European players in the lighting field that are established through these projects, with a continuous involvement of the Dutch SMEs, widening the scope to also include systems and services.

Linkage with other innovation instruments (e.g., public purchasing and risk investment)

Currently, LEDs are rapidly entering the market as replacement for less efficient incandescent lamps (either as retrofit lamps or as new modules). The potential of digital and connected lighting has recently started to be addressed, think of the most successful Philips HUE proposition (connected lighting for the consumer space).

The public authorities, owning a substantial fraction of the existing indoor and outdoor lighting infrastructure, can speed up the uptake of digital lighting in the Dutch market as a launching customer and through innovative purchasing. The public authorities will benefit from the additional savings offered by combining LED technology with controls, while the industry will be able to optimize his offer much faster based on the feedback obtained from the launching customer.

Collaboration in and leverage with European and multi-national policies and programs

This roadmap is closely linked with the European roadmap put together by the Photonics21 European Technology Platform. Philips Lighting chairs the work group dealing with “Advanced Lighting, Electronics and Displays”. People from TNO, Holst Centre and Philips Lighting were deeply involved in editing of the latter roadmap in collaboration with the relevant European players from academia, research industry, start-ups, SMEs and large industry.

Through this Photonics21 innovation roadmap we do align with the Photonics PPP work programmes in Horizon 2020, and by mobilizing the lighting eco-system it enables us to contribute substantially to several of the Key Enabling Technologies (KET). In order to further leverage the existing strength of the Dutch eco-system the HTSM lighting community calls upon the Dutch government:

- To maintain the Dutch commitment for international R&D in the framework of the EUREKA and the JU programmes to avoid losing the international connection and the additional funding from Europe
- To support the need to involve and fund (large) industry in FP9 and ECSEL2 programmes
- To invest more in innovation activities targeting lighting systems and services
- To take up a prominent role as launching customer

4. Partners and process

Partners in this roadmap from industry, science, departments, regions and cities

In previous versions, the following partners have been involved in the definition of this roadmap:

Academia	Radboud Universiteit, RUG, TU/e, TUD, UM, UMCG, Universiteit Leiden, UT, UU, UvA, UvT, WUR
Institutes	AMOLF, DIMES, TNO-ESI, Holst Centre, ILI, TNO Snellius, M2i, MESA+, TNO B&O, TNO D&V, TNO I&T, TNO ICT, VSL, Waag Society, Dekra, Dutch Polymer Institute
Industry	Applied Micro Electronics AME, Avantes, BESI-Fico, BIC Industries, Boschman Technologies, Cofely GDF Suez, DCD, Deerns, DevLab, EagleVision, Etap, Foreverlamp, Havells Sylvania, Innolumis, I-NRG, LED expert, LedNed, Lemnis, Lightronics, LuxLab, Machine Fabriek Otto Schouten B.V., MARAS, Massive, Mat-Tech, Metatronics, Nederlandse Licht Associatie (NLA), Noldus, NXP, OCE Technologies, OTB Solar, Paleco, PeerPlus, Philips, Plugwise, Quintor, Rena Electronica, Scheuten Solar, Seher, Somfy, Tass, Trilux, Vinotion, Wittenburg, Y'All Solutions

Process followed in creating and maintaining this roadmap (with role of SME)

Like in former times, Philips Lighting (being a global market leader in lighting solutions) has led the process to come to this updated HTSM Lighting roadmap document for the Netherlands. It reflects input gathered from various sources and includes inspiration from contacts with universities and knowledge institutes.

On 6 September 2017 a kick-off workshop event had been held at the High-Tech Campus in Eindhoven

for the roadmap update-process. It was titled “event “The new world of Lighting”. Different relevant parties have presented their running research activities and have shared their vision on trends and new directions relevant the Lighting research and industry in the Netherlands. This event was well attended by nearly 60 interested parties. The discussions in this workshop have been used as input material for this roadmap.

5. Investments [1]

Roadmap	**2015**	**2016**	**2017**	**2018**	**2019**
Industry	48.5	48.0	47.5	47.0	46.5
TNO	6	6	6	6	6
NLR					
NWO	2.6	2.6	2.6	2.0	2.0
Universities	5.0	5.0	5.0	5.0	5.0
Departments and regions (excluding TKI)	2.1	2.1	2.1	2.1	2.1
Grand total	**64.2**	**63.7**	**63.2**	**62**	**61.5**

European programs within roadmap	**2015**	**2016**	**2017**	**2018**	**2019**
Industry	12.0	12.0	12.0	11.5	11.5
TNO	4.8	4.8	4.8	4.8	4.8
NLR					
NWO					
Universities	4.0	4.0	4.0	4.0	4.0
EZ co-financing of European programs	2.1	2.1	2.1	2.1	2.1
European Commission co-financing	6.2	6.2	6.2	6.0	6.0

[1] R&D in public-private partnership, including contract research; all figures in million euro cash flow per year (cash plus in-kind contribution)